Upper Sacramento River Winter Chinook Salmon Carcass Survey

2007 Annual Report

A U.S. Fish & Wildlife Service Report

U.S. Fish & Wildlife Service
Red Bluff Fish & Wildlife Office
Red Bluff, California 96080
April 2008

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Abstract

Since 1996, the U.S. Fish & Wildlife Service and the California Department of Fish and Game have cooperated on an annual survey of winter Chinook salmon returning to the upper Sacramento River. The U.S. Fish & Wildlife Service's objective for participation in the survey is to collect data to evaluate the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery. Provided in this report is a summary of data from the 2007 Sacramento River winter Chinook carcass survey pertinent to evaluation of the supplementation program.

Return year 2007 was relatively small among the returns on record and the smallest since 2000, with an estimated 2,541 winter Chinook returning to the survey area. An estimated 139 of the winter Chinook were of hatchery-origin, representing approximately 5% of the total run. The percentage of age two males in the 2007 return was very small relative to recent years; whereas, the percentage of age four hatchery-origin fish was much greater. Temporal and spatial distributions of natural-origin and hatchery-origin fish were similar. The ratio of females to males was much greater for hatchery-origin than natural-origin fish. The number of pre-spawn mortalities was small for both natural-and hatchery-origin females.

Introduction

The Sacramento River system supports four distinct "runs" of Chinook salmon (*Oncorhynchus tshawytscha*): fall-run, late-fall-run, spring-run, and winter-run. Winter-run salmon leave the ocean and enter the Sacramento River from November through June in an immature reproductive state. They migrate into the upper reaches of the Sacramento River, hold in cool waters released from Shasta Dam, and spawn from May through August between the city of Red Bluff (river mile [RM] 245) and Keswick Dam (RM 302), the upstream limit of migration. Most winter Chinook salmon spawn at age three, with the remainder spawning at ages two and four (Hallock and Fisher 1985).

Winter Chinook salmon were listed as "threatened" under the Endangered Species Act in 1989 and their status was changed to "endangered" in 1994 (59 Federal Register 440). In 1989, the U.S. Fish and Wildlife Service (Service) began propagating winter Chinook salmon to supplement natural production. The winter Chinook salmon supplementation program was initially located at the Coleman National Fish Hatchery (NFH) on Battle Creek, a tributary of the Sacramento River. In 1998, the program was moved to the newly constructed Livingston Stone NFH located at the base of Shasta Dam, to increase returns to the main stem Sacramento River.

A primary objective of the winter Chinook carcass survey is to estimate the abundance of returning winter Chinook. Precise estimates of winter Chinook abundance are necessary to meet the delisting requirements for the species, which are specified in the draft recovery plan for winter Chinook salmon (National Marine Fisheries Service 1997). The Service and the California Department of Fish and Game (CDFG) initiated the carcass survey in 1996 to improve the precision of population estimates, which had previously been based on extrapolation of fish counts at the Red Bluff Diversion Dam. Population estimates derived from the carcass survey are listed in the electronic CDFG GrandTab population file, and explained in further detail in a complementary report from the CDFG (Killam 2007).

Additional objectives of the carcass survey are to (1) collect information on several important life history attributes of winter Chinook, including: age and gender composition of the spawning population, pre-spawning mortality rate, and temporal and spatial distributions of spawning, and (2) collect data useful in evaluating the winter Chinook supplementation program. The following report was prepared by the Service to address these objectives.

Methods

Study Area & Sampling Protocol

The 2007 carcass survey was conducted on the Sacramento River, California and was designed to encompass the primary spawning areas of winter Chinook salmon. The survey area covered approximately 27 miles of the Sacramento River and was divided into four reaches (Figure 1): reach 1 extended from the Keswick Dam (RM 302) to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Dam to the Highway 44 Bridge in Redding, California (RM 296); reach 3 extended from the Highway 44 Bridge to above Bourbon Island (RM 288.5), and reach 4 extended from above Bourbon Island to RM 276 just downstream of Ash Creek Road bridge.

The carcass survey was designed to include the entire winter Chinook spawning period and was conducted daily from May 1, 2007 through August 24, 2007 in 3-day cycles: reach 4 on the first day; reach 3 on the second day, and reaches 2 and 1 on the third day. The order that reaches were sampled was consistent throughout the survey.

The survey was conducted with at least two boats, each having one observer and one operator. Each boat surveyed from a shoreline to the middle of the river. Carcasses were recovered using a 4.9 meter pole with a five-pronged gig attached. Carcass condition was estimated as "fresh" or "non-fresh". A carcass was considered fresh if it had at least one clear eye, relatively firm body texture, or pink gills. Fresh carcasses were generally more intact than non–fresh carcasses and parameters such as length, gender, and spawn status could be determined more reliably. As a result, morphometric and other information in this report are based only on data from fresh carcasses unless otherwise noted.

Data gathered from carcasses included: date, location (reach, RM, and latitude / longitude), gender, spawn status (spawned, unspawned, and unknown), fork length, and adipose fin status (absent, present, and unknown). After data were collected, the carcass received an externally visible tag or was cut in half to ensure that the carcass was not resampled at a later date. Spawn status of females was defined as spawned (abdomen extremely flaccid or very few eggs remaining), unspawned (abdomen firm and swollen or many eggs remaining), or unknown (indeterminable spawn status, usually due to predation on the carcass). The spawn status of males was always categorized as unknown. Carcasses with an intact adipose fin were considered to be natural-origin and those with a missing adipose fin were considered to be hatchery-origin. The head was collected from all hatchery-origin carcasses so that the coded-wire tag (CWT) could be extracted and read at a later date (all hatchery-origin winter Chinook are coded-wire tagged as juveniles prior to release). Additionally, the head was collected from carcasses with an adipose fin status of "unknown" so it could be examined for the presence of a coded-wire tag. These carcasses were counted as hatchery-origin if they contained a coded-wire tag; if they did not, their classification remained "unknown". A small piece of fin tissue was taken and preserved for future genetic analysis from all hatchery-origin fish.

Data Analysis

Age two natural-origin carcasses were separated from age three and age four carcasses using length-frequency analysis (Ney 1993). The age of hatchery-origin carcasses was determined by decoding the CWT and identifying the fish's brood year relative to the return year. Spatial and temporal distribution, age composition, gender composition, and pre-spawn mortality were compared between hatchery-origin and natural-origin carcasses. It was assumed that longevity of natural-origin and hatchery-origin fish after spawning was the same. This assumption allowed for the relative comparison of spawn timing between the two groups based on the timing of carcass recovery.

Run Size Estimate of Hatchery-origin Winter Chinook

The number of non-fresh hatchery-origin winter Chinook salmon carcasses was expanded based on the proportion of fresh, hatchery-origin carcass among all fresh carcass recoveries (Appendix 1). The estimate of non-fresh hatchery-origin carcasses was added to the number of fresh hatchery-origin carcass recovered, and then expanded to include carcasses believed to have been present, but not observed, based on the Jolly-Seber mark-recapture method used by the CDFG (Killam 2007). Additional calculations were performed to accommodate carcasses for which "freshness" was not recorded, fish that did not receive an adequate fin clip when marked as juveniles (estimated from mark retention data), and hatchery-origin fish that were removed from the natural spawning population for use as brood stock at Livingston Stone NFH.

Results

Carcass Recoveries

A total of 1,581 carcasses were observed during the 2007 survey (62% of the estimated run size; Table 1), and 788 were sampled for biological data (744 of the carcasses sampled were fresh). Tissue samples were collected from 743 fresh carcasses (42 hatchery-origin, 695 natural-origin, and 6 of unknown origin). One non-winter hatchery-origin Chinook carcass (Feather River Spring Chinook) was recovered during the survey. There is no information to indicate that hatchery-origin winter Chinook strayed within or outside of the upper Sacramento River basin.

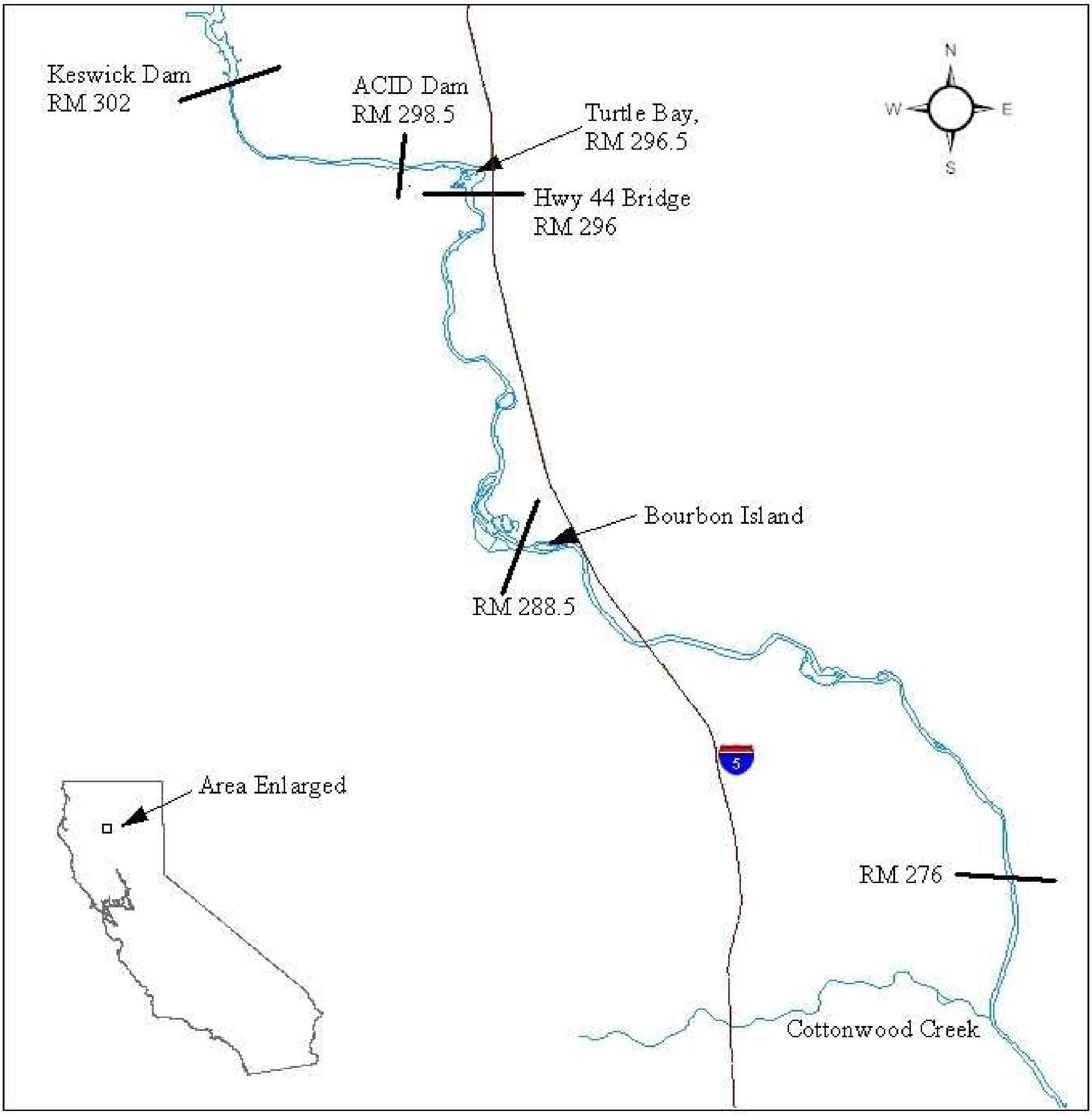

Figure 1. Sampling area of Sacramento River winter Chinook salmon carcass survey for return year 2007. Reach 1 extended from the Keswick Dam (RM 302) to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Dam to the Highway 44 Bridge in Redding, California (RM 296); reach 3 extended from the Highway 44 Bridge to above Bourbon Island (RM 288.5); and reach 4 extended from above Bourbon Island to RM 276.

Coded-Wire Tag Recoveries

Heads were collected from 91 carcasses (83 hatchery-origin and 8 unknown-origin) and readable coded-wire tags were recovered from 66 of the heads (tags were not detected in 25 heads; Appendix Table 1). None of the unknown-origin carcasses contained a coded-wire tag. Sixty-five of the recovered tags were from winter Chinook released from the Livingston Stone NFH and one (code 062411) was a stray spring Chinook salmon reared at the CDFG Feather River Hatchery. This stray fish, and the associated data, was removed from all analyses.

Hatchery-origin Returns

An estimated 139 hatchery-origin winter Chinook returned in 2007 representing 5.5 percent of the total run. Age three fish (brood year 2004) were the primary contributors to the 2007 return, and all of the 17 CWT groups released from this brood year were represented in the 2007 return (Table 2). Twenty age-four hatchery-origin winter Chinook were recovered during the survey, representing approximately 25% of the total hatchery returns. Only one age-two hatchery-origin carcass was recovered in 2007 (RM 287).

Temporal and Spatial Distribution

The temporal distributions of natural-origin and hatchery-origin carcasses in 2007 were nearly identical and within the range observed in previous years (Figure 2). The spatial distributions of natural-origin and hatchery-origin carcasses were also nearly identical in 2007 (Figure 3).

Age Composition and Length-at-Age

Only one age two hatchery-origin carcass was recovered and it was a male (Table 3). Length-at-age comparisons using hatchery-origin fish could not be conducted due to the small sample sizes available. Age three fish accounted for most of the hatchery-origin returns of winter Chinook salmon; however, returns of age-4 were greater than average. Carcasses of age three and age four natural-origin winter Chinook could not be distinguished using length-frequency analysis (Figure 4).

The frequency at length for return year 2007 fresh female natural-origin carcass recoveries was generally consistent with the average for return years 2001 – 2006; except for a slight increase in larger fish (approximately 850 – 900 mm). The same comparison with male data exhibited a definitive increase in the number of large fish (generally >950mm). This was the result of a relatively strong return of age-4 and a very weak return of age-2 and age-3 fish. The absence of well-defined modes in the length-frequency histograms of natural-origin carcasses precluded distinguishing carcasses of age three and age four fish. Additionally, comparison of length-at-age between natural-origin and hatchery-origin carcasses was precluded by uncertainties regarding age at return for these two groups.

Gender Ratio

In 2007, as in previous surveys, substantially more female than male carcasses were recovered (Table 4). Among natural-origin fish observed in 2007, females outnumbered males 2.62 to 1 and among hatchery-origin fish, females outnumbered males by 7.20 to 1.

Pre-spawning Mortality

In 2007, the overall percentage of female pre-spawn mortalities was small for both natural and hatchery fish. However, compared to previous years, the percentage of female carcasses recovered that were categorized as “not fully spawned” was above average for natural-origin but, below average for hatchery-origin carcasses (Table 5). Typical of most years, the percent not spawned was greater for hatchery-origin females.

Table 1. Sacramento River winter Chinook salmon estimated run size, carcasses observed, and percent at age by origin and gender, return years 2001 – 2007.

Total

Return Year	Total Estimated Runsize[a]	Hatchery-origin Runsize	% of Run Hatchery-origin	Total Carcasses Observed	Percent of Run Observed	River miles Surveyed, From : To	Natural-origin, % at Age[b] Age 2	Natural-origin, % at Age[b] Ages 3 & 4	Hatchery-origin, % at Age[c] Age 2	Hatchery-origin, % at Age[c] Age 3	Hatchery-origin, % at Age[c] Age 4
2001	8,224	513	6.2	5,145	62.6	288 : 302	9.0	91.0	23.0	77.0	0.0
2002	7,464	921	12.3	4,946	66.3	288 : 302	6.5	93.5	12.5	85.6	1.9
2003	8,218	474	5.8	4,536	55.2	286 : 302	2.7	97.3	8.5	90.6	0.9
2004	7,869	633	8.0	3,279	41.7	273 : 302	12.3	87.7	27.3	71.1	1.6
2005	15,839	3,092	19.5	8,772	55.4	273 : 302	4.4	95.6	4.9	95.0	0.1
2006	17,205	2,382	13.8	7,699	44.7	275 : 302	0.9	99.1	0.1	95.5	4.3
2007	2,542	139	5.5	1,581	62.2	276 : 302	4.0	96.0	0.0	74.6	25.4
Mean	9,623	1,165	12.1	5,137	53.4	.	5.1	94.9	5.9	91.4	2.7

Female

Return Year	Natural-origin, % at Age[b] Age 2	Natural-origin, % at Age[b] Ages 3 & 4	Hatchery-origin, % at Age[c] Age 2	Hatchery-origin, % at Age[c] Age 3	Hatchery-origin, % at Age[c] Age 4
2001	0.2	99.8	3.2	96.8	0.0
2002	1.2	98.8	0.0	98.8	1.2
2003	0.2	99.8	0.0	98.9	1.1
2004	0.9	99.1	0.0	97.3	2.7
2005	0.3	99.7	0.0	100.0	0.0
2006	0.1	99.9	0.0	97.7	2.3
2007	0.6	99.4	0.0	76.1	23.9
Mean	0.4	99.6	0.1	98.7	1.2

Male

Return Year	Natural-origin, % at Age[b] Age 2	Natural-origin, % at Age[b] Ages 3 & 4	Hatchery-origin, % at Age[c] Age 2	Hatchery-origin, % at Age[c] Age 3	Hatchery-origin, % at Age[c] Age 4
2001	25.4	74.6	47.1	52.9	0.0
2002	21.2	78.8	59.1	36.4	4.5
2003	15.9	84.1	43.5	56.5	0.0
2004	39.7	60.3	64.8	35.2	0.0
2005	15.8	84.2	19.5	80.0	0.5
2006	4.3	95.7	0.5	89.8	9.7
2007	13.7	86.3	0.0	63.1	36.9
Mean	19.9	80.1	21.9	74.1	4.0

[a] Run size was estimated by the California Department of Fish and Game and was reported by that agency as part of the Sacramento River winter Chinook salmon carcass survey effort (objective three).

[b] The number of age 2 natural-origin fish was estimated using length-frequency analysis. Age 2 fish were considered less than or equal to the following fork lengths (mm), by return year, females and males, respectively: 2001: 580, 690; 2002: 550, 680; 2003: 560, 670; 2004: 580, 690; 2005: 580, 670; 2006: 580, 670; 2007: 580, 680. Age of hatchery-origin carcasses was determined by coded-wire tag.

[c] Age of hatchery-origin carcasses was determined by coded-wire tags recovered at or above river mile 288 (consistency among years).

Table 2. Winter Chinook salmon returns by brood year, coded-wire tag groups contributing to return, return rate, and returns at age for brood years 1999 – 2005. Returns in 2007 were from brood years 2003 (age four fish), 2004 (age three fish), and 2005 (age two fish).

Brood	No. of CWT grps. contributing to		Avg. family	Number	Total CWTs	Return	CWT Returns at Age[a]		
year[b]	Release[c]	Return	grps. per CWT grp.	Released[d]	Recovered	Rate (%)[e]	Age 2[b]	Age 3[b]	Age 4[b]
1999	17	17	1.0	30,367	162	0.533	32	129	1
2000	30	29	3.2	162,198	138	0.085	17	119	2
2001	27	21	3.7	180,686	123	0.068	12	110	1
2002	32	32	2.7	154,920	1313	0.848	59	1221	33
2003	31	31	3.0	180,908	823	0.455	67	736	20
2004	17	17	4.3	124,861	45	0.036[f]	1	44	NA[f]
2005	18	NA[f]	3.1	151,320	1	NA[f]	1	NA[g]	NA[g]

[a] Adult returns are based on all CWT returns including fresh and unfresh carcasses from all sampling activities (including those other than the carcass survey).

[b] Fish return as: Age 2 (Brood year + 2 years), Age 3 (Brood year + 3 years), and Age 4 (Brood year + 4 years).

[c] Releases from the captive broodstock program are not included.

[d] Number released reflects only those with a CWT and clipped adipose fin as estimated from tag retention data prior to release.

[e] Return rate (%) was calculated by dividing (number of CWTs recovered) by the (number of CWTs released), multiplied by 100.

[f] Return rate not final, returns not yet complete.

[g] Not available.

Table 3. Fork length (mm) of age two male Sacramento River winter Chinook salmon by origin, return years 2001 – 2007.

Return Year	Natural-origin[a]				Hatchery-origin			
	n	Mean	Min	Max	n	Mean	Min	Max
2001	162	563	400	690	24	539	390	390
2002	71	578	460	680	8	550	470	470
2003	56	521	410	650	10	518	420	420
2004	162	581	430	680	35	545	440	440
2005	132	555	410	660	38	551	450	450
2006	20	556	440	640	1[b]	-	540	540
2007	25	555	440	670	1	-	550	550

[a]The maximum length of natural-origin age two males was estimated through length-frequency analysis.

[b] Non-fresh carcass.

Table 4. Gender ratio of Sacramento River winter Chinook salmon carcasses by origin, return years 2001 – 2007.

Return Year	Natural-origin			Hatchery-origin		
	Females (F)	Males (M)	F:M	Females (F)	Males (M)	F:M
2001	1,179	639	1.85	61	51	1.20
2002	927	335	2.77	81	22	3.68
2003	1,899	352	5.39	98	23	4.26
2004	1,009	472	2.14	75	56	1.34
2005	2,452	885	2.77	600	203	2.96
2006	1,905	738	2.58	324	100	3.24
2007	534	204	2.62	36	5	7.20
Mean	1,415	518	2.73	182	66	2.77

Table 5. Pre-spawn mortality of female Sacramento River winter Chinook salmon by origin, return years 2001 – 2007.

Return year	Natural-origin			Hatchery-origin		
	Total carcasses	Number not fully spawned[1]	Percent not fully spawned[1]	Total carcasses	Number not fully spawned[1]	Percent not fully spawned[1]
2001	1,176	10	0.85	61	0	0.00
2002	925	19	2.05	81	3	3.70
2003	1,899	11	0.58	98	0	0.00
2004	988	7	0.71	75	4	5.33
2005	2,392	35	1.46	600	24	4.00
2006	1,905	25	1.31	324	23	7.10
2007	513	9	1.75	36	1	2.78
Mean	1,400	17	1.18	182	8	4.31

[1] "Not fully spawned" includes female carcasses classified as "unspawned" and "partially spawned".

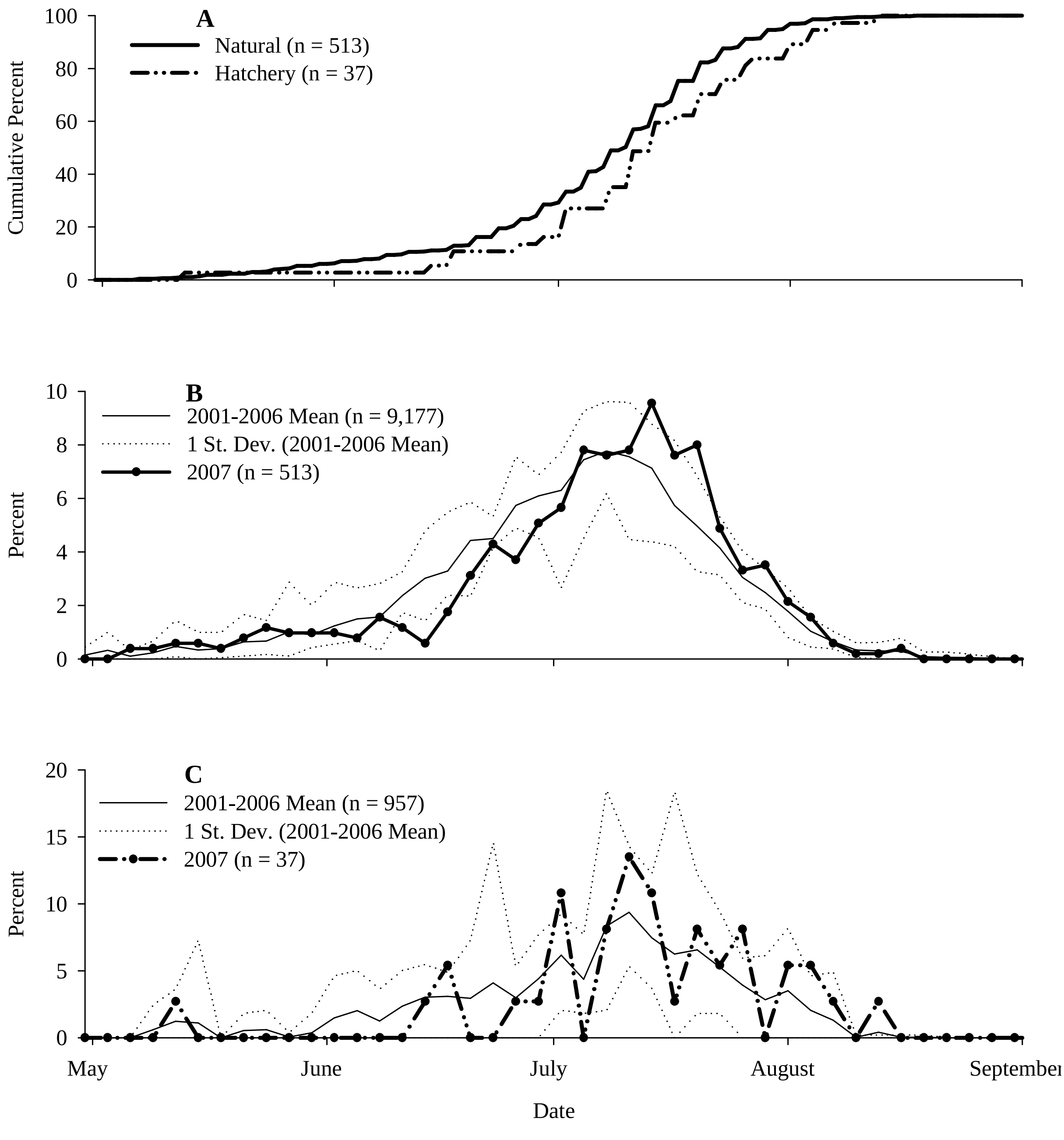

Figure 2. Temporal distribution of fresh, female Sacramento River winter Chinook salmon carcass recoveries for return year 2007. Represented is the cumulative percent of natural and hatchery winter Chinook salmon recovered by date for return year 2007 (**A**) and a comparison of the total percent that returned by date with the mean observed for return years 2001 – 2006 for natural (**B**) and hatchery fish (**C**).

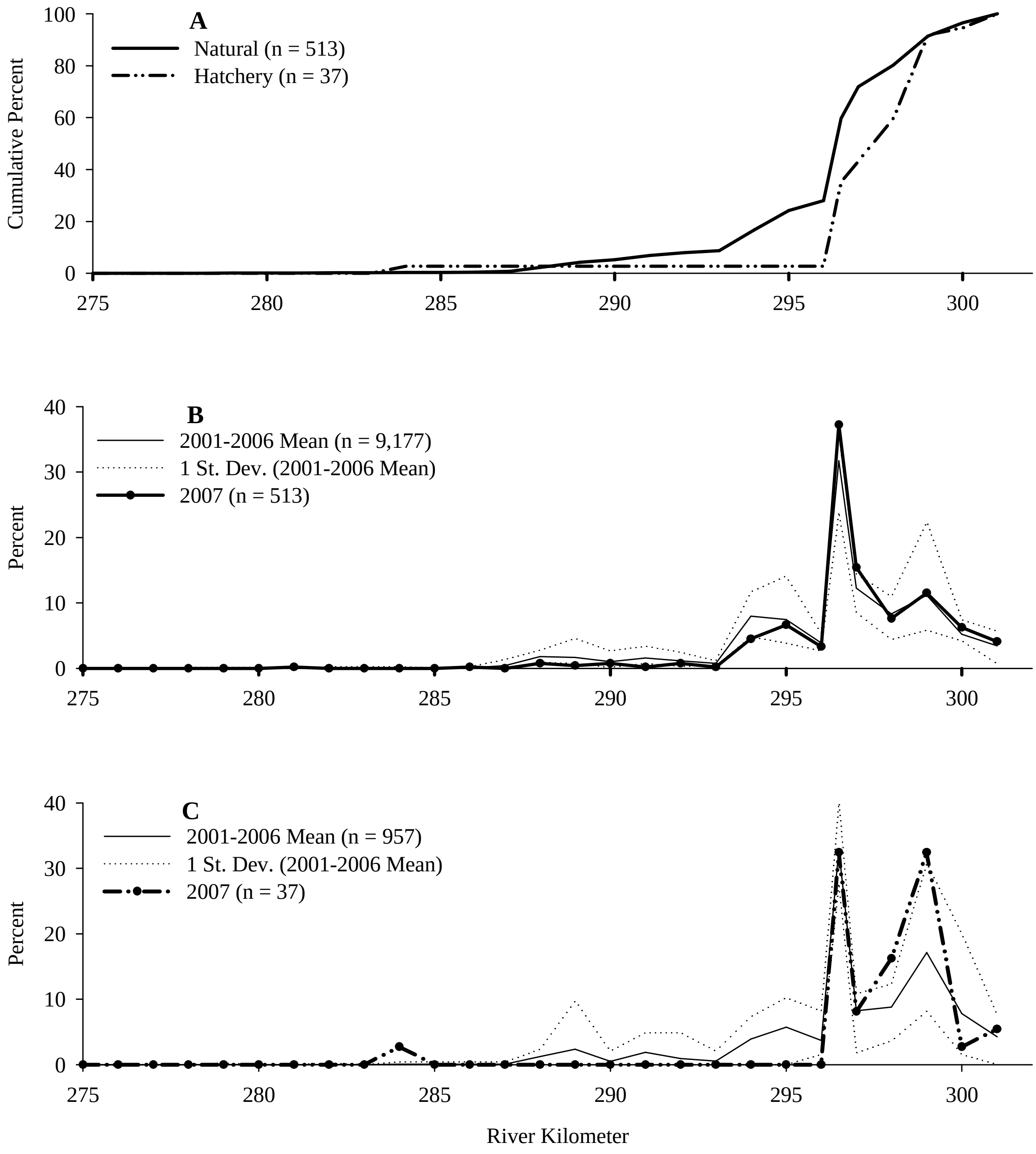

Figure 3. Spatial distribution of fresh, female Sacramento River winter Chinook salmon carcass recoveries for return year 2007. Represented is the cumulative percent of natural and hatchery winter Chinook salmon recovered by river mile for return year 2007 (**A**) and a comparison of the total percent recovered by river mile with the mean observed for return years 2001 – 2006 for natural (**B**) and hatchery fish (**C**).

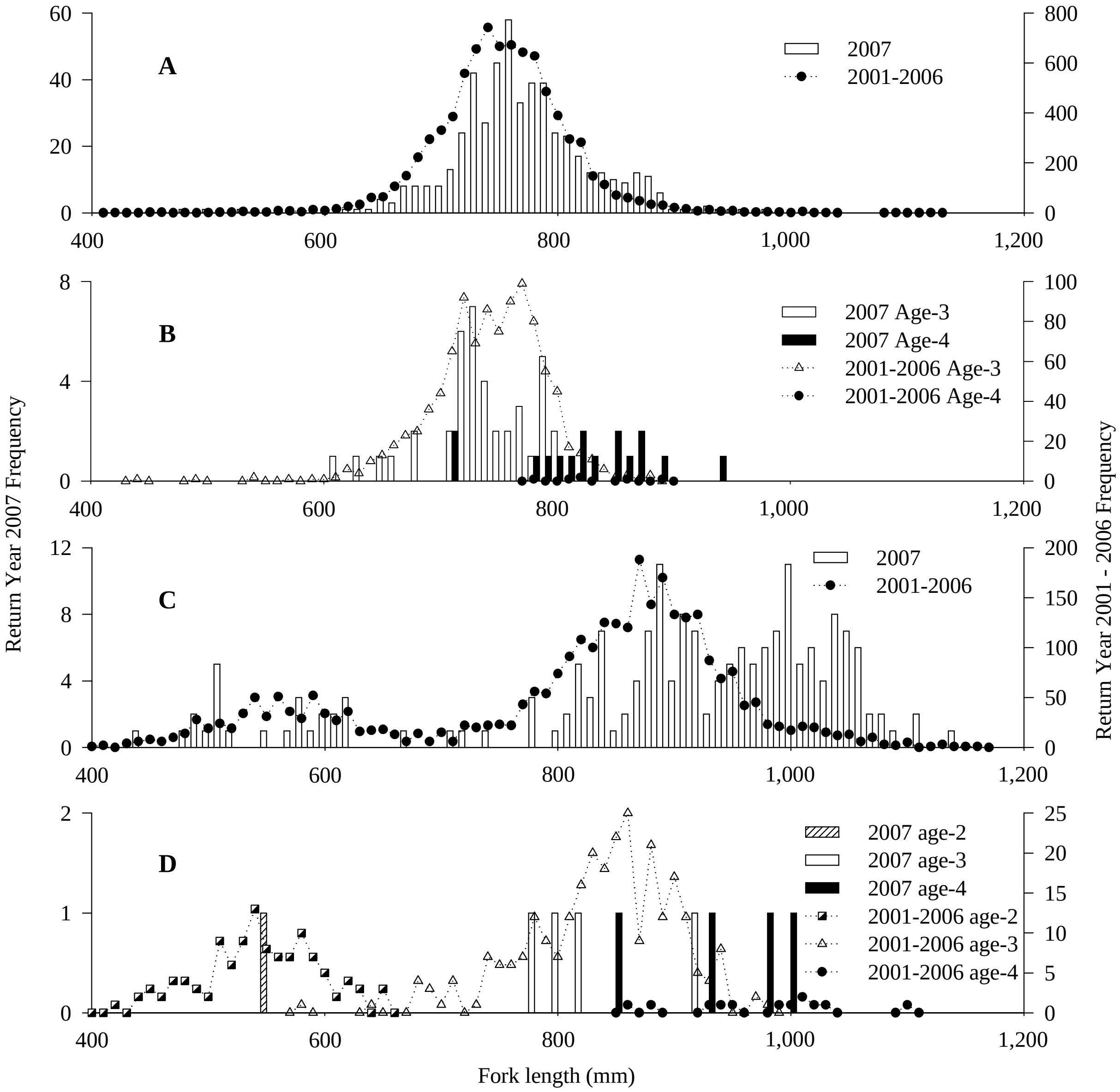

Figure 4. Winter Chinook salmon length-frequency distribution comparison of fresh carcass recoveries for return year 2007 and the mean from return years 2001 – 2006: (A) natural-origin females, (B) hatchery-origin females, (C) natural-origin males, and (D) hatchery-origin males.

Discussion

In contrast to the winter Chinook salmon return size in 2006 that was the largest since 1981, the return in 2007 was the smallest since 2000 (Killam 2007). Approximately 62% of the run was handled in 2007 which was among the largest proportion of run observed in recent survey years. Hatchery origin fish represented approximately 5.5% of the total run.

Temporal and spatial distributions between natural-origin and hatchery-origin fish were similar to previous years. The slight reduction in the number of carcasses recovered downstream is likely a result of fewer overall spawning Chinook salmon and a reduced competition for primary spawning areas upstream. Pre-spawning mortality was minimal for both hatchery- and natural-origin fish.

Too few hatchery-origin fish containing a coded wire tag were recovered for any meaningful age comparison to natural-origin recoveries. However, of the few recoveries, age-4 fish represented a significantly large proportion relative to previous years (USFWS 2001, 2002, 2003, 2004, 2005, and 2006). This large proportion of age-4 fish is a reflection of the small number of age-2 and age-3 fish returning in 2007. Separation of the age-3 and age-4 component among natural-origin fish cannot be validated without proper ageing.

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Acknowledgements

Funding for this project was supplied from Central Valley Project Improvement Act, Comprehensive Assessment and Monitoring Program funds. Data were collected through a cooperative effort of U.S. Fish & Wildlife Service and California Department of Fish and Game personnel. Kevin Offill prepared this report and Kevin Niemela, Bob Null, Laura Mahoney, and Doug Killam provided editorial review.

Appendix A-1. Estimated escapement of hatchery-origin winter Chinook salmon in the upper Sacramento River for 2007.

Methods and Equations

Total abundance of hatchery-origin winter Chinook salmon returning to the upper Sacramento River was estimated following a series of expansions to account for potential biases and difficulties in identifying hatchery-origin carcasses and recovering coded-wire tags. The number of hatchery-origin Chinook carcasses was expanded to: 1. account for unrecognized fin clips and undetected coded-wire tags in non-fresh carcasses, 2. include carcasses not observed during the survey, 3. account for fish taken into Livingston Stone NFH for use as brood stock, and 4. to include hatchery-origin fish that did not have a clipped adipose fin. Descriptions of these expansions follow:

1. Expansion of non-fresh carcasses for decreased coded-wire tag recovery and fin clip recognition.

Non-fresh hatchery-origin carcass recoveries were expanded based on the recovery rate of fresh hatchery-origin carcasses ($H_{NF\text{-}Exp}$):

$$H_{NF\text{-}Exp} = (H_{F\text{-}Obs} \times T_{NF\text{-}Obs}) / T_{F\text{-}Obs} \qquad (1)$$

where,
$H_{F\text{-}Obs}$ = number of fresh hatchery-origin carcasses,
$T_{NF\text{-}Obs}$ = total number of non-fresh hatchery- and natural-origin carcasses, and
$T_{F\text{-}Obs}$ = total number of fresh hatchery- and natural-origin carcasses recovered during the carcass survey.

2. Expansion for adipose fin clipped hatchery-origin carcasses believed to be present in the upper Sacramento River, but not observed during the survey (H_{Sac}).

This expansion was based on the proportion of hatchery-origin carcasses observed during the carcass survey to the total estimated escapement of naturally reproducing winter Chinook salmon in the upper Sacramento River (this excludes fish retained as brood stock by the Livingston Stone NFH), based on the Jolly-Seber population estimate ($N_{J\text{-}S}$):

$$H_{Sac} = (H_{NF\text{-}Exp} + H_{F\text{-}Obs} + H_{Unk}) / T_{Obs} \times N_{J\text{-}S} \qquad (2)$$

where,
H_{Unk} = number of hatchery-origin carcasses with an unknown “freshness” and
T_{Obs} = the total number of carcasses observed during the carcass survey (including fresh and non-fresh and hatchery- and natural-origin carcasses).

3. Hatchery-origin fish captured for use as brood stock at Livingston Stone NFH ($LSNFH_H$) were accounted for by adding them to H_{Sac}. Addition of these fish yielded the total number of adipose fin clipped hatchery-origin fish present in the upper Sacramento River and at the Livingston Stone NFH (H_{Clip}):

$$H_{Clip} = H_{Sac} + LSNFH_H \tag{3}$$

4. To account for non-adipose fin clipped hatchery-origin fish, H_{Clip} was expanded based on mark retention rates measured prior to release of the winter Chinook as juveniles.

- H_{Clip} was apportioned among each recovered tag code (CWT_{App}):

$$CWT_{App} = H_{Clip} \times (CWT_{Rec} / CWT_T) \tag{4}$$

where,
CWT_{Rec} = the number of coded-wire tags recovered for an individual tag code and
CWT_T = the total number of all coded-wire tags recovered.

- CWT_{App} was expanded to include all hatchery-origin fish without an adipose fin clip (CWT_{Final}) based on tag retention rates measured prior to release of winter Chinook juveniles.

$$CWT_{Final} = CWT_{App} / (J_{Clip} / J_{Obs}) \tag{5}$$

where,
J_{Clip} = the number of juveniles observed with an adipose fin clip during tag retention studies prior to release, by individual tag code and
J_{Obs} = the total number of juveniles observed during tag retention studies prior to release, by individual tag code.

- Lastly, CWT_{Final} was summed to obtain the estimate of total hatchery-origin winter Chinook salmon (H_{Total}).

$$H_{Final} = \Sigma\, CWT_{Total} \tag{6}$$

Data

41 =	$H_{F\text{-}Obs}$	=	Number of fresh hatchery carcass recoveries
795 =	$T_{NF\text{-}Obs}$	=	Number of non-fresh hatchery and natural carcass recoveries
785 =	$T_{F\text{-}Obs}$	=	Number of fresh hatchery and natural carcass recoveries
1,580 =	T_{Obs}	=	Total carcasses observed during the carcass survey
2,487 =	$N_{J\text{-}S}$	=	Total naturally reproducing winter Chinook salmon escapement
54 =	$LSNFH_H$	=	Hatchery fish retained for LSNFH broodstock
0 =	H_{Unk}	=	Total hatchery fish with unknown carcass condition

For calculations using ‘Juvenile Tag Retention Data’:

C = fish with an adipose fin clip
NC = fish with no adipose fin clip
T = fish with a coded-wire tag
NT = fish with no coded-wire tag

Appendix Table 1. Coded-wire tag codes recovered during the 2007 run year, by recovery location, with juvenile tag retention data. (For calculations using 'Juvenile Tag Retention Data': C = fish with an adipose fin clip, NC = fish with no adipose fin clip, T = fish with a coded-wire tag, NT = fish with no coded-wire tag.)

	CWT_{Rec}		Juvenile tag retention data			
CWTCode	Survey	LSNFH	T/C	NT/C	T/NC	NT/NC
051681	2		434	161	4	1
051683	5		420	174	6	0
051684	1		524	73	3	0
051685	2		535	62	3	0
051686	3		507	93	0	0
051687	5	1	436	160	4	0
051688	2		543	55	2	0
051689	2		505	86	7	2
051690	2	1	503	96	1	0
051691	3	1	542	56	1	1
051692	3	1	540	54	6	0
051693	2		556	40	4	0
051694	2	1	548	50	2	0
051695	3		504	95	1	1
051696	2		591	108	2	0
051964	2		199	1	0	0
051966	1		198	2	0	0
051967	1		199	1	0	0
051969	1		196	3	1	0
051973	1		200	0	0	0
051976	1		200	0	0	0
051980	2		199	1	0	0
051982	1		198	2	0	0
051985	1		200	0	0	0
051988	1		199	1	0	0
051990	4	1	199	1	0	0
051993	1		199	1	0	0
051994	1		195	5	0	0
051996	2		199	1	0	0
052476	2		486	114	0	0
052477	3		556	37	7	0
052481	1		173	27	0	0
051983		1	197	3	0	0
052492		1	185	15	0	0
	65	8				

Calculations

1. Non-fresh carcass expansion based on fresh carcass recovery rate

$$\left(\underset{41}{\underline{H_{F\text{-}Obs}}} \times \underset{795}{\underline{T_{NF\text{-}Obs}}} \right) / \underset{785}{\underline{T_{F\text{-}Obs}}} = \underset{\mathbf{42}}{\underline{H_{NF\text{-}Exp}}}$$

2. Expansion to include carcasses not observed

$$\left(\underset{41.5223}{\underline{H_{NF\text{-}Exp}}} + \underset{41}{\underline{H_{F\text{-}Obs}}} + \underset{0}{\underline{H_{Unk}}} \right) / \underset{1{,}580}{\underline{T_{Obs}}} \times \underset{2{,}487}{\underline{N_{J\text{-}S}}} = \underset{\mathbf{130}}{\underline{H_{Sac}}}$$

3. Addition of hatchery-origin fish retained for Livingston Stone NFH brood stock

$$\underset{129.9465}{\underline{H_{Sac}}} + \underset{8}{\underline{LSNFH_{H}}} = \underset{\mathbf{138}}{\underline{H_{Clip}}}$$

Appendix Table 2. Estimated number of hatchery-origin winter Chinook salmon returning in 2007 by tag code, following expansions to account for coded-wire tag loss from non-fresh carcasses and carcasses present, but not observed.

CWTCode		H_{Clip}			CWT_{Rec}		CWT_T			CWT_{App}
051681	:	137.9465	×	(	2	/	73	)	=	**3.8**
051683	:	137.9465	×	(	5	/	73	)	=	**9.4**
051684	:	137.9465	×	(	1	/	73	)	=	**1.9**
051685	:	137.9465	×	(	2	/	73	)	=	**3.8**
051686	:	137.9465	×	(	3	/	73	)	=	**5.7**
051687	:	137.9465	×	(	6	/	73	)	=	**11.3**
051688	:	137.9465	×	(	2	/	73	)	=	**3.8**
051689	:	137.9465	×	(	2	/	73	)	=	**3.8**
051690	:	137.9465	×	(	3	/	73	)	=	**5.7**
051691	:	137.9465	×	(	4	/	73	)	=	**7.6**
051692	:	137.9465	×	(	4	/	73	)	=	**7.6**
051693	:	137.9465	×	(	2	/	73	)	=	**3.8**
051694	:	137.9465	×	(	3	/	73	)	=	**5.7**
051695	:	137.9465	×	(	3	/	73	)	=	**5.7**
051696	:	137.9465	×	(	2	/	73	)	=	**3.8**
051964	:	137.9465	×	(	2	/	73	)	=	**3.8**
051966	:	137.9465	×	(	1	/	73	)	=	**1.9**
051967	:	137.9465	×	(	1	/	73	)	=	**1.9**
051969	:	137.9465	×	(	1	/	73	)	=	**1.9**
051973	:	137.9465	×	(	1	/	73	)	=	**1.9**
051976	:	137.9465	×	(	1	/	73	)	=	**1.9**
051980	:	137.9465	×	(	2	/	73	)	=	**3.8**
051982	:	137.9465	×	(	1	/	73	)	=	**1.9**
051985	:	137.9465	×	(	1	/	73	)	=	**1.9**
051988	:	137.9465	×	(	1	/	73	)	=	**1.9**
051990	:	137.9465	×	(	5	/	73	)	=	**9.4**
051993	:	137.9465	×	(	1	/	73	)	=	**1.9**
051994	:	137.9465	×	(	1	/	73	)	=	**1.9**
051996	:	137.9465	×	(	2	/	73	)	=	**3.8**
052476	:	137.9465	×	(	2	/	73	)	=	**3.8**
052477	:	137.9465	×	(	3	/	73	)	=	**5.7**
052481	:	137.9465	×	(	1	/	73	)	=	**1.9**
051983	:	137.9465	×	(	1	/	73	)	=	**1.9**
052492	:	137.9465	×	(	1	/	73	)	=	**1.9**
										138

Appendix Table 3. Estimated number of hatchery-origin winter Chinook salmon returning in 2007 by tag code, following the final expansion to account for hatchery-origin fish without an adipose fin clip.

CWTCode		CWT_{App}		J_{Clip}		J_{Obs}		CWT_{Final}
051681	:	3.7794	/ (	595	/	600	) =	**3.8**
051683	:	9.4484	/ (	594	/	600	) =	**9.5**
051684	:	1.8897	/ (	597	/	600	) =	**1.9**
051685	:	3.7794	/ (	597	/	600	) =	**3.8**
051686	:	5.6690	/ (	600	/	600	) =	**5.7**
051687	:	11.3381	/ (	596	/	600	) =	**11.4**
051688	:	3.7794	/ (	598	/	600	) =	**3.8**
051689	:	3.7794	/ (	591	/	600	) =	**3.8**
051690	:	5.6690	/ (	599	/	600	) =	**5.7**
051691	:	7.5587	/ (	598	/	600	) =	**7.6**
051692	:	7.5587	/ (	594	/	600	) =	**7.6**
051693	:	3.7794	/ (	596	/	600	) =	**3.8**
051694	:	5.6690	/ (	598	/	600	) =	**5.7**
051695	:	5.6690	/ (	599	/	601	) =	**5.7**
051696	:	3.7794	/ (	699	/	701	) =	**3.8**
051964	:	3.7794	/ (	200	/	200	) =	**3.8**
051966	:	1.8897	/ (	200	/	200	) =	**1.9**
051967	:	1.8897	/ (	200	/	200	) =	**1.9**
051969	:	1.8897	/ (	199	/	200	) =	**1.9**
051973	:	1.8897	/ (	200	/	200	) =	**1.9**
051976	:	1.8897	/ (	200	/	200	) =	**1.9**
051980	:	3.7794	/ (	200	/	200	) =	**3.8**
051982	:	1.8897	/ (	200	/	200	) =	**1.9**
051985	:	1.8897	/ (	200	/	200	) =	**1.9**
051988	:	1.8897	/ (	200	/	200	) =	**1.9**
051990	:	9.4484	/ (	200	/	200	) =	**9.4**
051993	:	1.8897	/ (	200	/	200	) =	**1.9**
051994	:	1.8897	/ (	200	/	200	) =	**1.9**
051996	:	3.7794	/ (	200	/	200	) =	**3.8**
052476	:	3.7794	/ (	600	/	600	) =	**3.8**
052477	:	5.6690	/ (	593	/	600	) =	**5.7**
052481	:	1.8897	/ (	200	/	200	) =	**1.9**
051983	:	1.8897	/ (	200	/	200	) =	**1.9**
052492	:	1.8897	/ (	200	/	200	) =	**1.9**
								139